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Cut-Off Determination Based On Well Log and Economics, Betung Field Jambi Sub-Basin, South Sumatera Basin

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Abstrack

The Betung Field is one of the oil and gas fields located in the Jambi Sub-Basin, South Sumatra Basin with the target of the Air Benakat Formation sandstone reservoir. The cut off value is determined based on the character of the reservoir to eliminate non-contributing rock volumes. Economically, the cut-off value of oil production can be calculated by oil prices and budgeted total costs. There are 4 layers (L-2, L-3, L-4 and L-5), where Layer 5 (L-5) is the research focus in the cut-off determination method. The methodology in this cut-off study used qualitative and quantitative analysis in three (3) wells out of ten (10) wells L-5 in the Betung Field. The primary data used are well logs, production data and economic data. The well log data is processed to obtain the petrophysical value of the wells. The petrophysical results will be analyzed and the cut-off will be determined for each well and layer in L-5. Production and economic data are processed to obtain cut-off clay content (Vclay) which aims to strengthen the cut-off results from petrophysical yields. Based on the results of calculations and analysis, layer five (1-5), the Betung Field has a cut-off clay content (Vclay) $\leq$ 34.2%; porosity $\geq$ 15.8%, water saturation $\leq$ 83.3%.

Keywords: *cut-off, petrophysic, well log*

I. Introduction

The lower limit value of the reservoir parameter to eliminate non-contributing rock volumes is the definition of cut-off (Worthington, 2010). Cut-off limits certain reservoir parameter values, namely Vclay, porosity, water saturation, where the cut-off value depends on the expected minimum permeability ability, viscosity and economic factors (Mahbaz et al., 2011). This research is focused on the cut-off analysis of the Air Benakat Formation, Betung Field, Jambi Sub-Basin-South Sumatra Basin.

The Betung field research location is located in the Jambi Sub-Basin which regionally includes the South Sumatra Basin (Barber et al., 2005) (Figure 1). The Barisan Mountains are a tertiary volcanic arc from the South Sumatra Basin. The area of this basin is about 330 x 510 km^2, where the southwest is bounded by the Pre-Tertiary outcrops of the Barisan hill, the eastern part is bounded by the Sunda Shelf, the western part is bounded by the Tigapuluh Mountains and the southeastern part is bounded by the Lampung High (Salim et al., 1995).

Figure 1. Location of the Jambi-South Sumatra Basin Research Area (Barber et al., 2005)

The Stratigraphy of the South Sumatra Basin consists of the Pre-Tertiary Group, the Kikim Tuff Formation and the older Lemat or Lahat Formation, the Lemat Muda or Lahat Muda Formation, the Talang Akar Formation, the Baturaja Formation, the Telisa Formation (Gumai), the Lower Palembang Formation (Air Benakat), the Middle Palembang Formation. (Muara Enim), Upper Palembang Formation (Kasai) (De Coster, 1974). The Air Benakat Formation is the focus of research, where this Formation was deposited during the early phase of the regression cycle. The composition of this formation consists of glauconitic sandstones, claystones, siltstones and sandstones containing carbonate elements. The thickness of this formation varies from 3300 – 5000 ft (about 1000 – 1500 m). The fauna found in the Lower Palembang Formation include *Orbulina universa* d'Orbigny, *Orbulina suturalis* Bronimann, *Globigerinoides subquadratus* bronimann, *Globigerina venezuelana* Hedberg, *Globorotalia Peripronda* Blow & Banner, *Globorotalia venezuelana* Hedberg, *Globorotalia peripronda* Blow & Banner, *Globorotalia mayeri* Cushman & Ellisor, which shows the age of Middle Miocene N12-N13. This formation was deposited in a shallow marine environment (De Coster, 1974) (Figure 2)

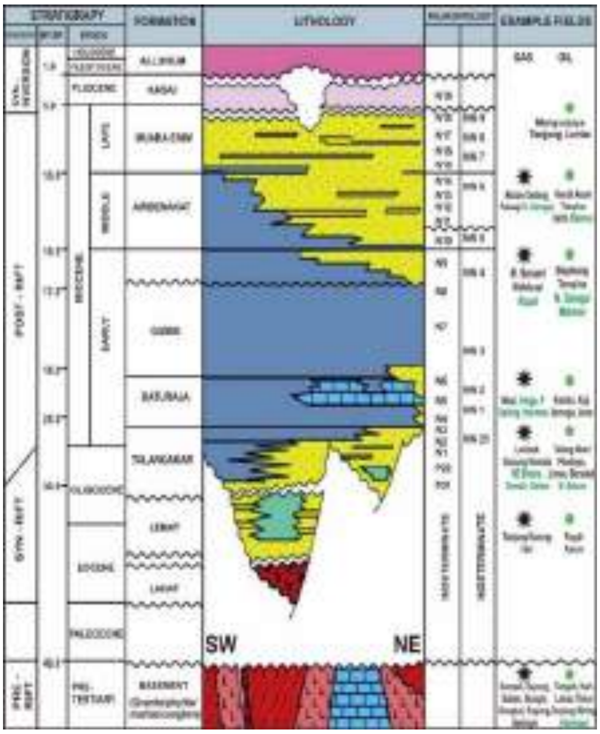


Figure 2. Stratigraphy of the South Sumatra Basin (Ginger dan Fielding, 2005)

In the cut-off analysis, petrophysical calculations and analysis are carried out first. Petrophysics is the study of the physical properties of rocks. According to Asquith, 1982, to determine the productive zone, the depth and thickness of a zone, the type of fluid in the reservoir, and estimation of hydrocarbon reserves, it is necessary to carry out a petrophysical analysis, where shale/clay content, porosity and water saturation are important petrophysical parameters in a formation.

- Clay Content

Analysis of the clay content was carried out by calculating the clay content in the sandstone reservoir using Gamma Ray logs. This calculation is used to interpret formations containing clay, where the results will affect the effective porosity, permeability and resistivity. Determination of clay content is obtained by calculating the volume of clay from Gamma Ray:

$$Vclay = \frac{GRlog - GRmin}{GRmax - GRmin} \quad (1)$$

Information:
Vclay : Volume/content of clay content
Grlog : Gamma Ray log
Grmin : Minimum Gamma Ray log
Grmax : Maximum Gamma Ray log

- Porosity

Porosity analysis was carried out using the results of well log measurements determined by Density analysis, Neutron analysis and Neutron-Density analysis. Equation for porosity calculation:

$$Ød = \frac{(\rho m - \rho b)}{(\rho m - \rho f)} \quad (2)$$

Information:
Ød : Porosity density log
ρm : Density matrix, gr/cc
ρb : Density of rock, gr/cc
ρf : Formation density, gr/cc

- Water Saturation

The resistivity log is used to determine water saturation. The research area uses the Simandoux equation, in which the formation contains not only sand but also clay in the sand content.

$$Sw = \frac{a.\ Rw}{Ø^m}\left[\sqrt{\frac{Vsh}{Vrh}^2 + \frac{4.Ø}{a.Rw.Rt}}^{\,m}\right] - \left(\frac{Vsh}{Rsh}\right) \quad (3)$$

Information:
Sw : Water saturation
Rw : Formation water resistivity
Rt : Resistivity of the formation
Ø : Effective porosity
Vsh : Volume shale
Rsh : Resistivity shale

- Cut-Off

The definition of cut-off is literally a limit value. The limit values of the reservoir parameters, namely volume of clay (Vclay), porosity (Ø) and water saturation (Sw) are the meaning of cut-off in the sense of a reservoir. Rock volumes that do not significantly contribute to the evaluation of IOIP or reservoir reserves, will be eliminated with a cut-off. The character of the reservoir determines the value of the cut-off.

II. Method

The methodology in this cut-off study used qualitative and quantitative analysis in three (3) wells out of ten (10) L-5 wells in the Betung Field. The primary data used are well logs, production data and economic data. The well log data is processed to obtain the petrophysical value of the wells. The petrophysical results will be analyzed and the cut-off will be determined for each well and layer in L-5. Production and economic data are processed to obtain cut-offs aimed at strengthening the cut-off results from petrophysical yields. The research flow can be seen in Figure 3.

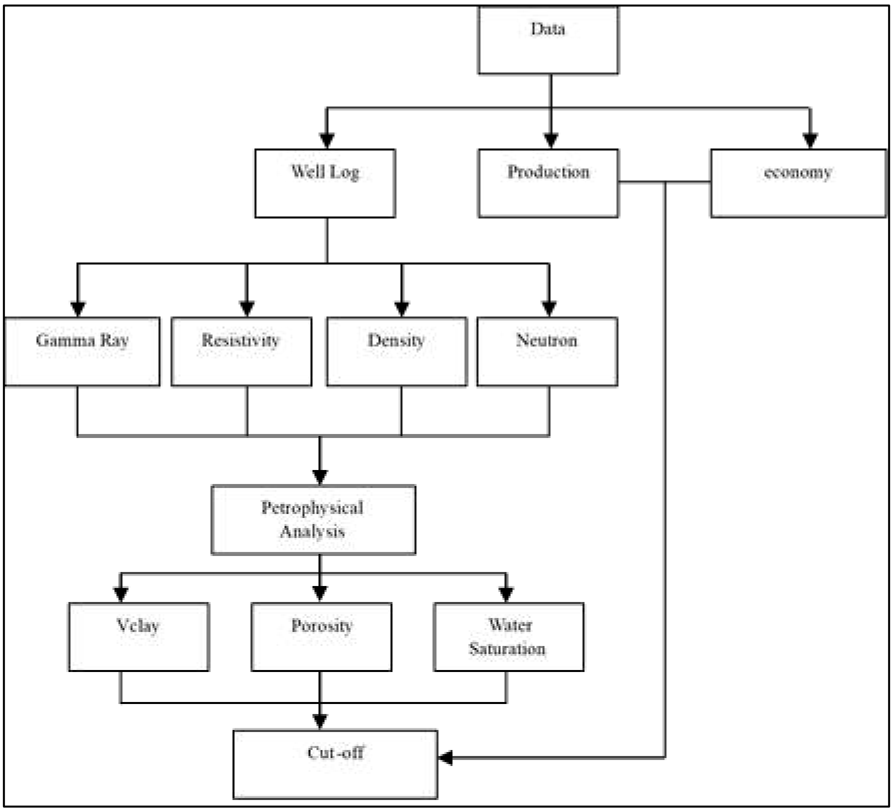


Figure 3. Cut-off Research Flow

III. Results and Discussion

The wells used in this research are well 209; well 219 and well 221. Petrophysical calculations were carried out using log data.

- Clay Content (Vclay)

The Gamma Ray log is used in the calculation of the clay content. The results of calculating the clay content (Vclay) use equation (1) (Table 1). The higher the Gamma Ray value, the higher the clay content, which is based on the measured radioactive level of the formation. Potassium (K), Thorium (Th) and Uranium (U) are the most common radioactive minerals. The Gamma Ray log also measures the degree of clay content in rocks. The presence of clay content in the formation greatly affects the porosity value.

Table 1. Clay Content (Vclay) of Well L-5

Well	**Top (mMD)**	**Bottom (mMD)**	**Avg. Vcl (dec)**
209	230,00	265,00	0,2054
219	236,52	269,74	0,4568
221	290,17	331,01	0,6539

- Porosity Calculation

The porosity-neutron-density log model was used to calculate the porosity. Porosity calculations use equation (2), where the results can be seen in Table 2. Log porosity readings of the response in the interconnected spaces between rocks that have been filled with hydrocarbons are carried out to determine the effective porosity. In the Betung Field, the effective porosity varies because it is influenced by several factors, namely grain shape, cementation, grain size, compaction and distribution of the rock constituents.

Table 2. Porosity Values of L-5 Wells

Well	**Top (mMD)**	**Bottom (mMD)**	**Avg. Porosity (dec)**
209	230,00	265,00	0,2322
219	236,52	269,74	0,2535
221	290,17	331,01	0,2432

- Calculation of Water Saturation

Water saturation calculation using resistivity log. resistivity log will show the same value if the fluid content is the same. Fluids containing hydrocarbons have a large resistivity value, while fluids containing water have a low resistivity value. Calculation of water saturation in the Betung Field uses equation (3). The results of the calculations can be seen in Table 3. The reasons for the variation in the content of these values are influenced by the size and distribution of rock pores, the height of the free water level, and differences in capillary pressure

Table 3. Water Saturation Values of Wells L-5

Well	**Top (mMD)**	**Bottom (mMD)**	**Sw (des)**
209	230,00	265,00	0,5161
219	236,52	269,74	0,3408
221	290,17	331,01	0,8225

- Cut-off determination

The cut-off value of clay content is determined by the distribution of clay volume values in the form of a crossplot between the clay volume value and the Porosity value. The limit of the cut-off value is determined based on the crossing line which will later be determined by the maximum volume value of clay with the minimum value of reservoir porosity L-5 in the Air Benakat Formation. Based on the calculations, the cut-off values for the L-5 wells can be seen in Table 4 and Figure 4-16.

Table 4. Cut-off of Wellsl L-5

Well	Cut off Vclay	Cut Off Porosity	Cut off Water Saturation
209	≤ 0,334	≥ 0,162	≤ 0,942
219	≤ 0,530	≥ 0,108	≤ 0,860
221	≤ 0,592	≥ 0,113	≤ 0,777

For cut-off layer 5 (L-5) the average cut-off from the wells in L-5 is used. Based on calculations, the L-5 cut-off for clay content (Vclay) < 0.342 (34.2%); porosity > 0.158 (15.8%), water saturation < 0.833 (83.3%).

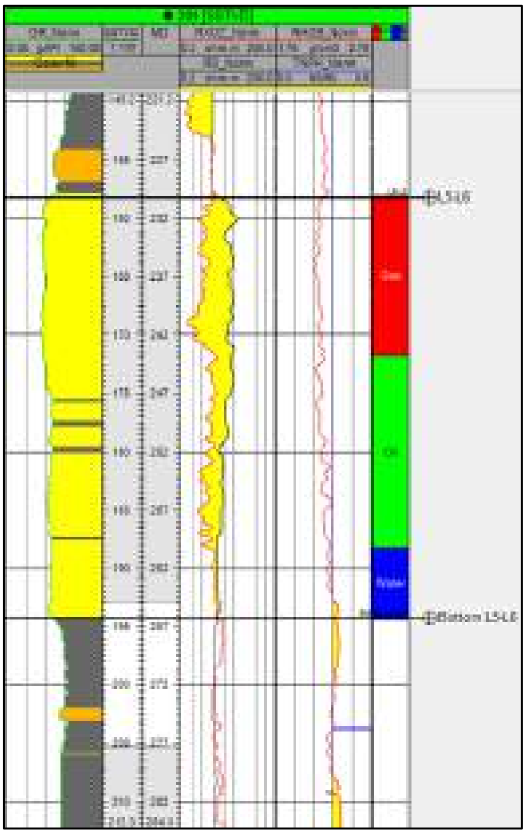


Figure 4. Petrophysics of well 209 L-5

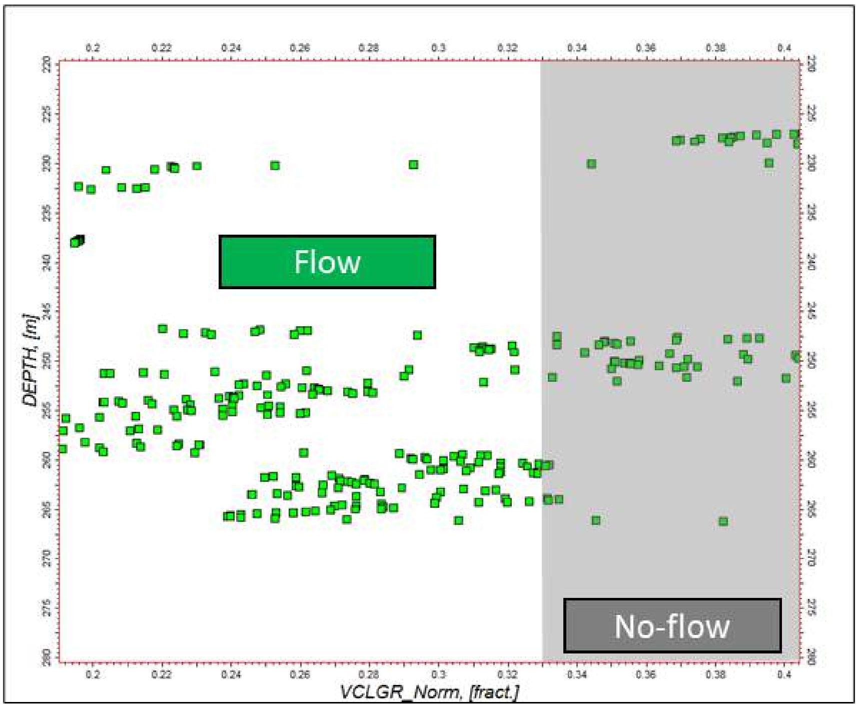


Figure 5. Cut-off Vclay of well 209 L-5

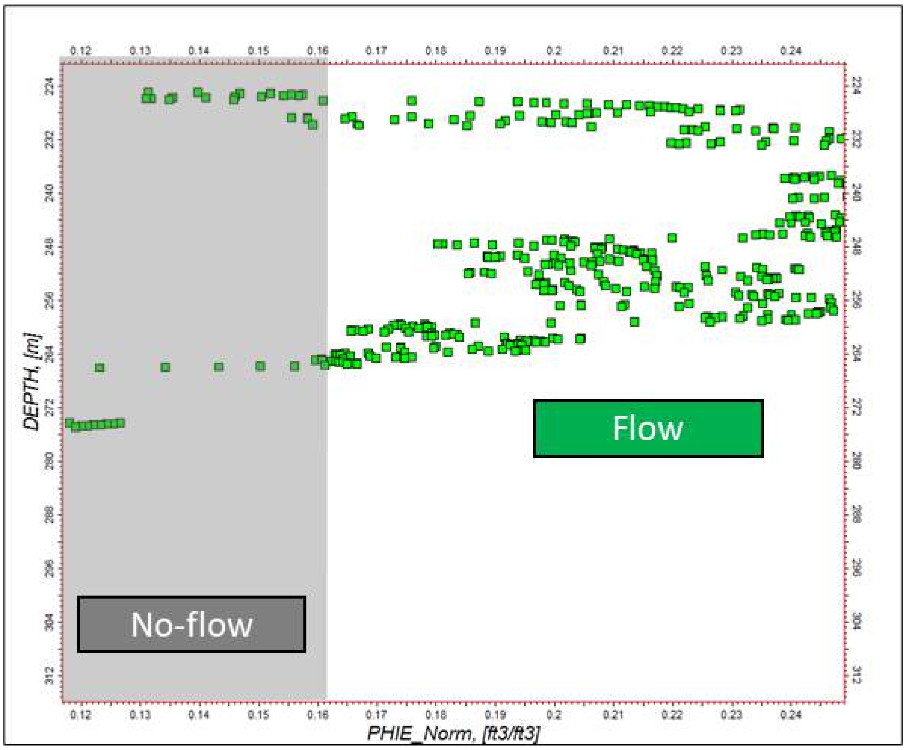


Figure 6. Porosity cut-off of well 209 L-5

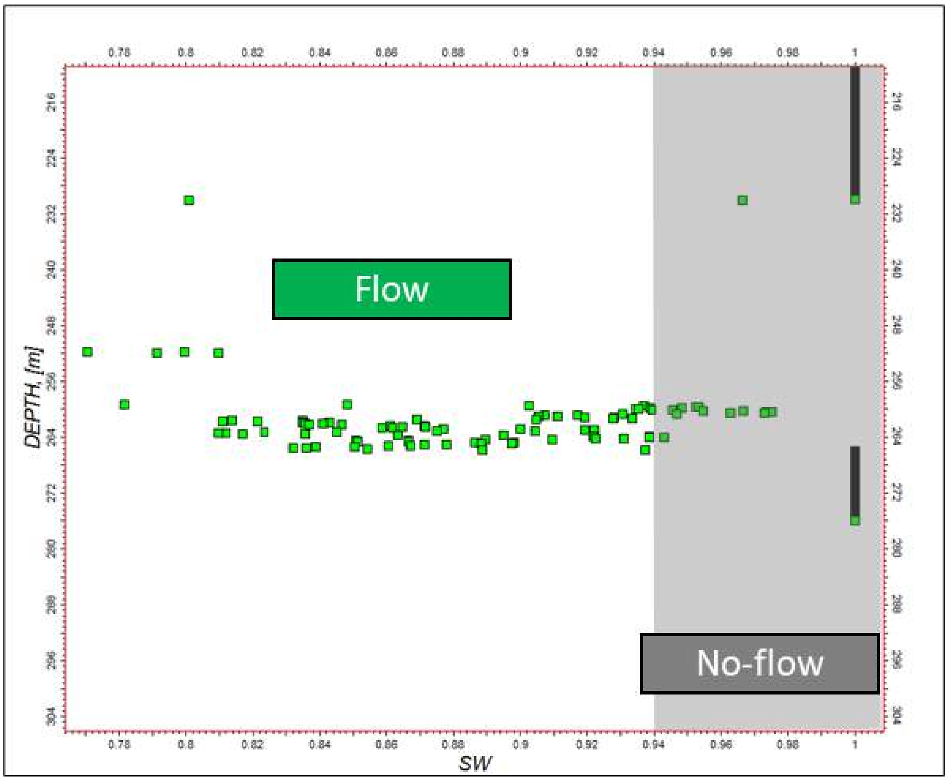


Figure 7. Cut-off Water Saturation of Well 209 L-5

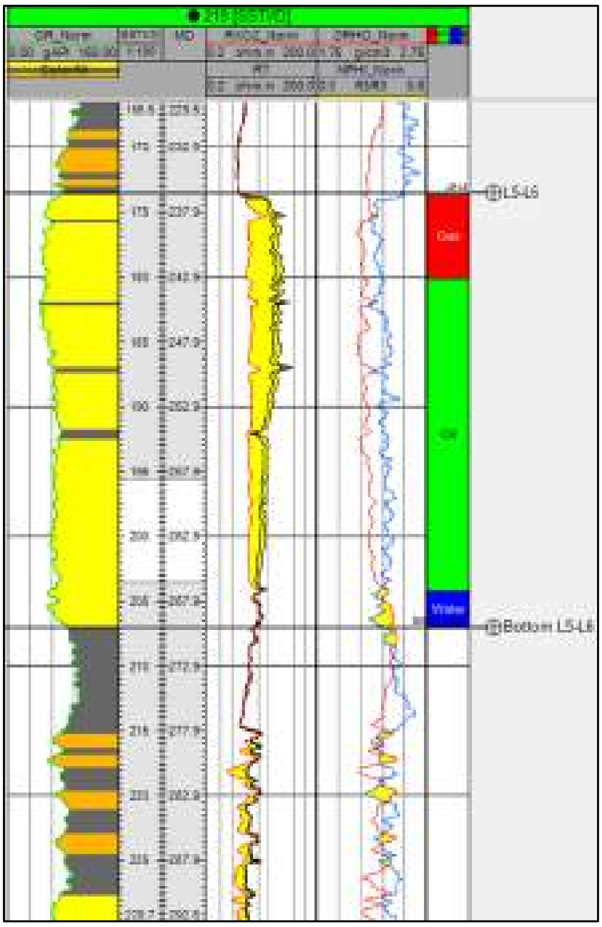


Figure 8. Petrophysics of well 219 L-5

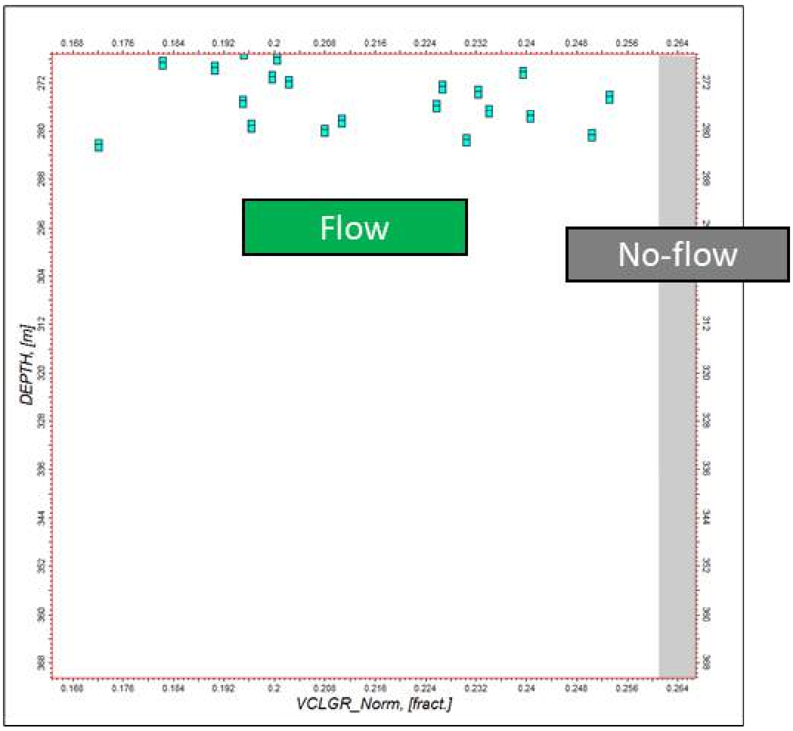


Figure 9. Cut-off Vclay of well 219 L-5

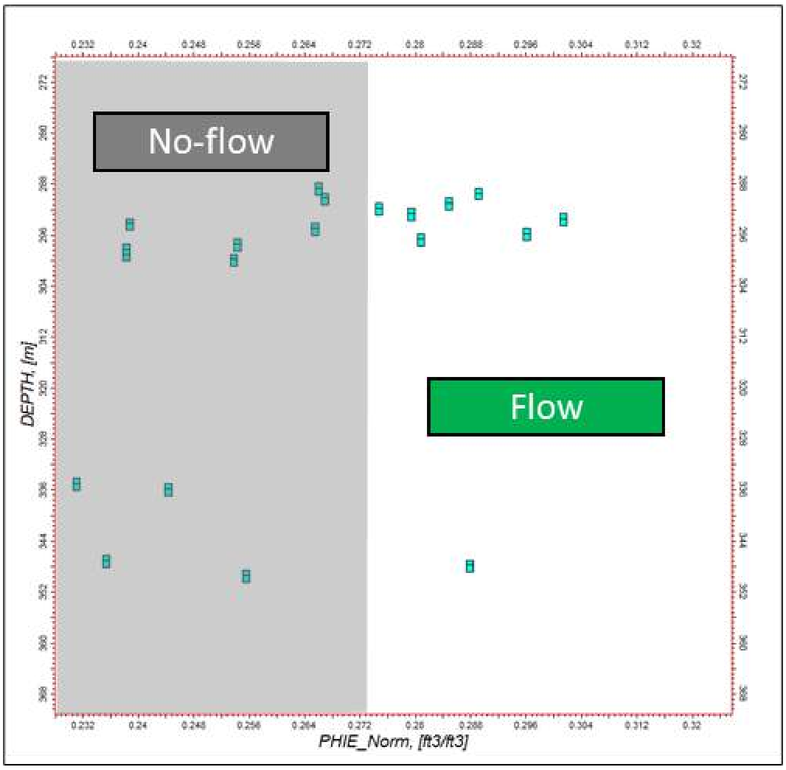


Figure 10. Cut-off Porosity of well 219 L-5

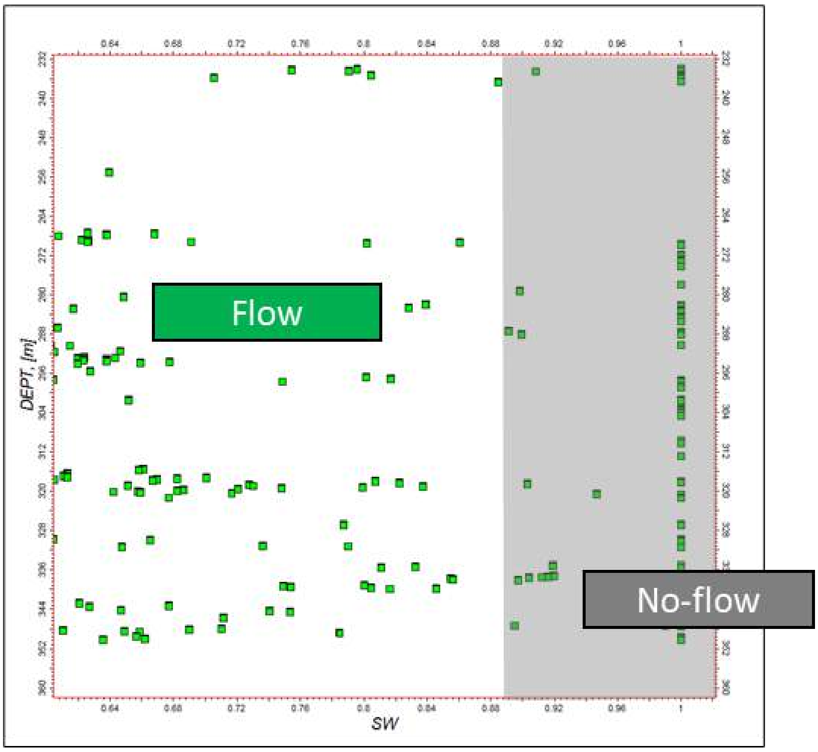


Figure 11. Cut-off Water Saturation of well 219 L-5

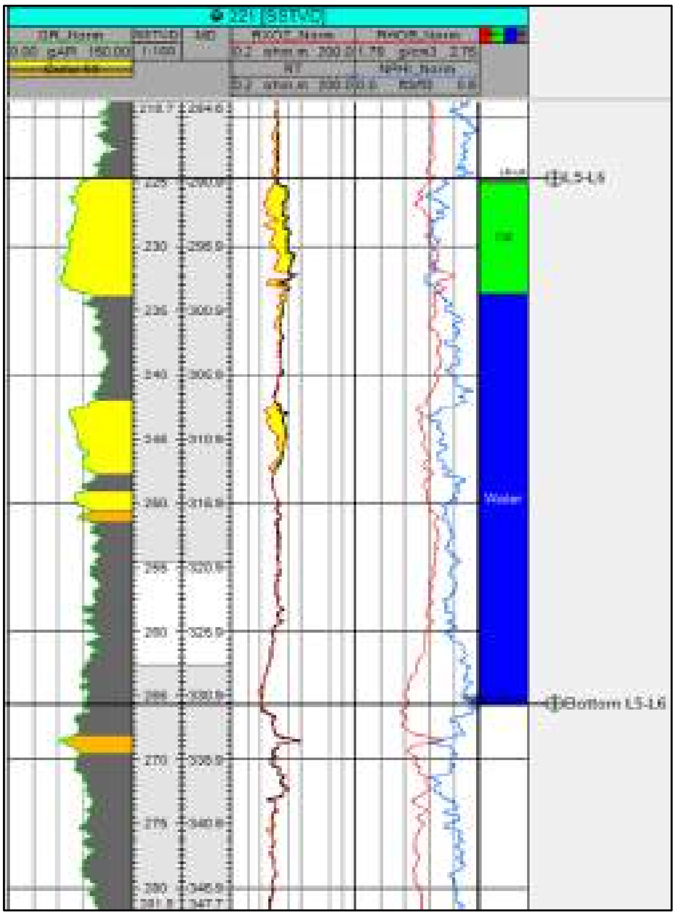


Figure 12. Petrophysics of well 221 L-5

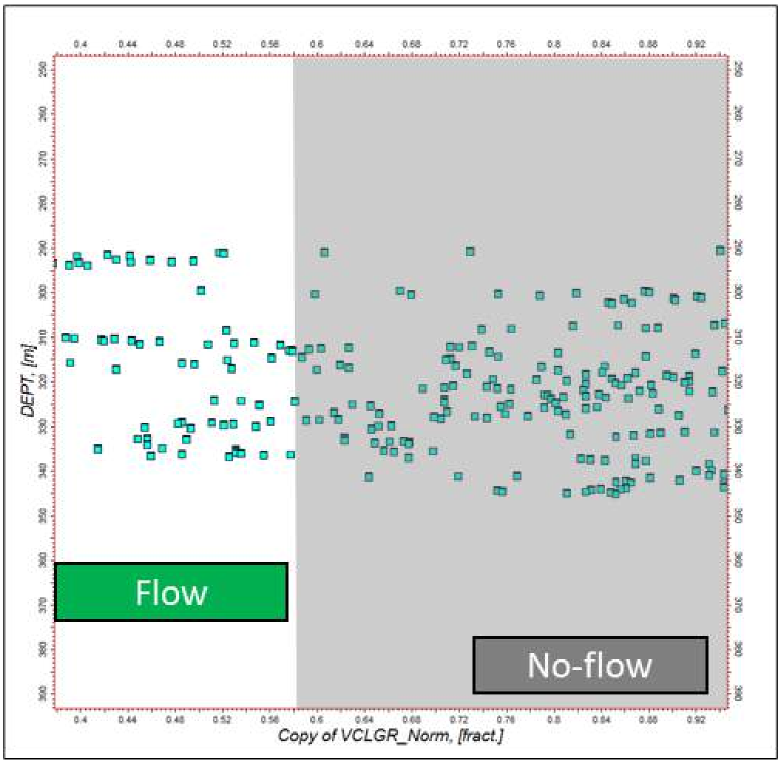


Figure 13. Cut-off Vclay of well 221 L-5

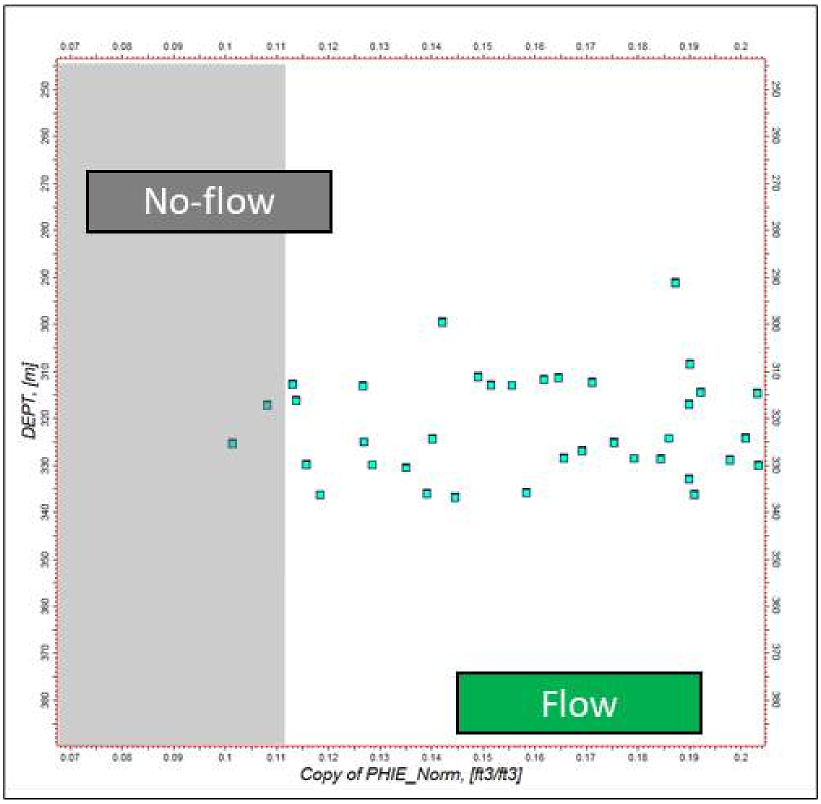


Figure 14. Cut-off Porosity of well 221 L-5

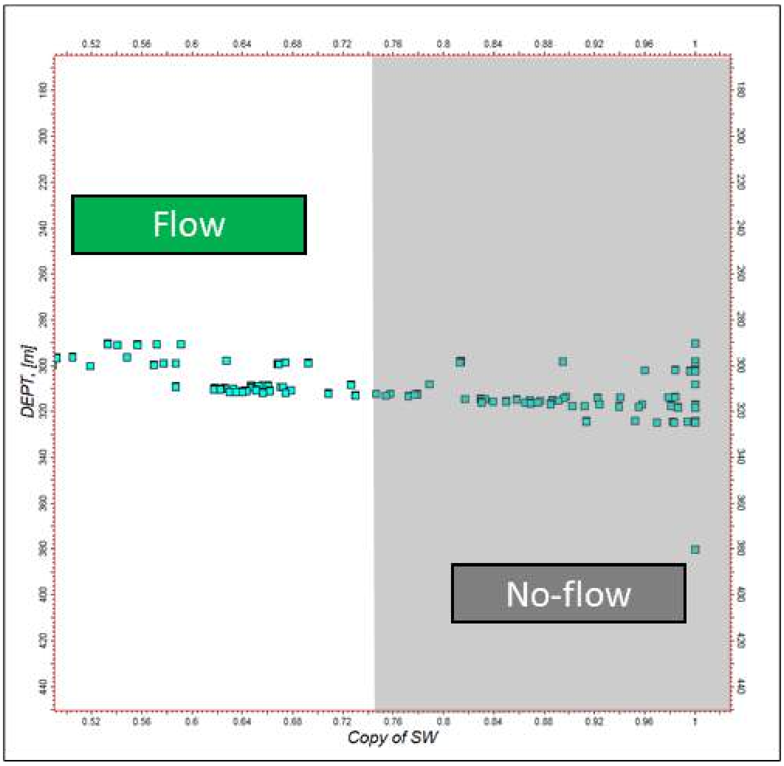


Figure 15. Cut-off Well Water Saturation of well 221 L-5

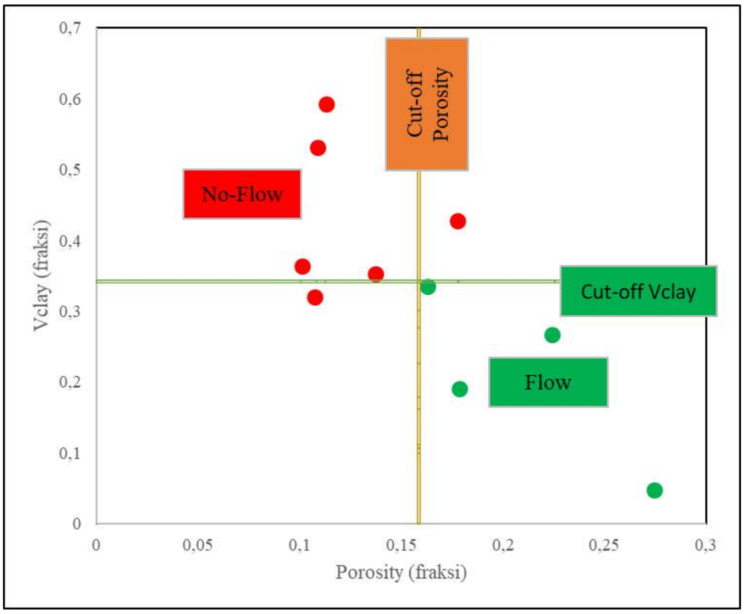


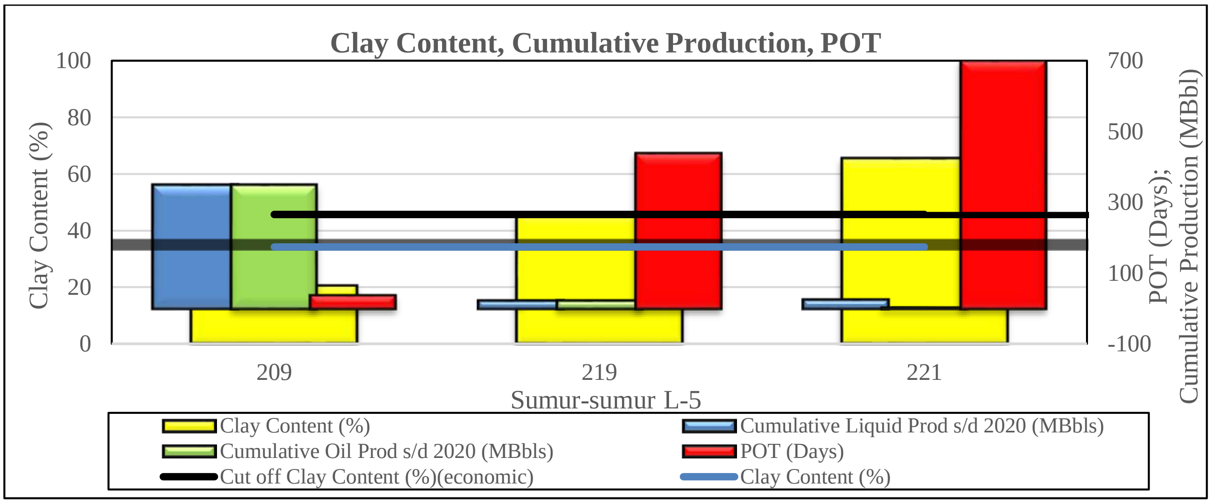
Figure 16. Cut-off Layer 5 (L-5)

Based on economics, the cut-off value of oil production can be calculated by oil prices and total budgeted costs (Yu & Wang, 2000; Ren et al., 2005). In economic analysis, the shorter the payback period, the more prospective or feasible the investment is (MD Sentosa et al., 2015). Processing the economic data of wells L-5, it can be seen that well 219 and well 221 have small cumulative oil production so that the Pay Out Time (POT) is long, where the POT for well 221 until April 2022 has not been reached, while well 219, the POT reached 439 days (Table 5). POT takes into account drilling costs, toll fees, crude oil prices (ICP), cumulative production. Based on the calculation of these parameters, the POT of each well is obtained as shown in Table 5.

Table 5. POTS of Wells L-5

Well	Clay Content (%)	Cumulative Liquid Production s/d 2020 (MBbls)	Cumulative Oil Production Oil s/d 2020 (MBbls)	Pay Out Time (Days)
09	20,54	347,923	347,798	38
219	45,68	22,963	22,963	439
221	65,39	26,236	2,975	Not yet reached

Thus, economically the clay content of well 219 of 45.68% (Table 1) is the cut-off limit which affects the small cumulative oil production and the duration of the POT of the well (Figure 17).



Figurer 17. Cut-off Clay Content

IV. Conclusion

Based on the results of calculations and cut-off analysis using well logs and the economics of layer 5 (L-5) of the Betung Field, it is obtained:

1. Layer 5 (L-5) is a hydrocarbon zone with clay content (Vclay), porosity and Water Saturation (Sw) based on petrophysical analysis: well 209 (Vclay: 0.2054; porosity: 0.2322; Sw: 0.5161); well 219 (Vclay: 0.4568; porosity: 0.2535; Sw: 0.3408); well 221 (Vclay: 0.6539; porosity: 0.2432; Sw: 0.8225)
2. Cut-off clay content (Vclay), porosity and water saturation (Sw) based on petrophysical analysis: well 209 (Vclay: $\leq$ 0.334; porosity: $\geq$ 0.162; Sw: $\leq$ 0.942); well 219 (Vclay: $\leq$ 0.530; porosity: $\geq$ 0.108; Sw: $\leq$ 0.860); well 221 (Vclay: $\leq$ 0.592; porosity: $\geq$ 0.113; Sw: $\leq$ 0.777)
3. Cut-off layer 5 (L-5) based on the average petrophysical analysis of the wells at L-5: Vclay < 0.342; porosity > 0.158%, water saturation < 0.833.
4. The cut-off based on economic calculations obtained the clay content (Vclay) of well 219 of 0.4568 (45.68%), which is a cut-off that affects the small cumulative oil production and the duration of the well POT.

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